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(54) **ARC WELDING METHOD AND APPARATUS FOR ARC WELDING**

LICHTBOGENSCHWEISSVERFAHREN UND VORRICHTUNG ZUM LICHTBOGENSCHWEISSEN

PROCÉDÉ DE SOUDAGE À L'ARC ET APPAREIL DE SOUDAGE À L'ARC

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(73) Proprietor: **ESAB AB**
402 77 Göteborg (SE)

(72) Inventors:
- **LENNARTSSON, Daniel**
  SE-705 94 Örebro (SE)
- **JOHANSSON, Tomas**
  SE-695 91 Laxa (SE)
- **ANDREN, Ulf**
  SE-695 72 Röfors (SE)
- **MELIN, Bo**
  SE-695 91 Laxa (SE)

(74) Representative: **AWA Sweden AB**
P.O. Box 11394
404 28 Göteborg (SE)

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Description

TECHNICAL FIELD

[0001] The invention relates to an arc welding method and an apparatus for arc welding, particularly for submerged arc welding comprising an electrode assembly with a multitude of electrodes (see, for example, JP 2005 342723 A).

BACKGROUND OF THE INVENTION

[0002] Submerged arc welding is a fully mechanised welding method characterised by high productivity and quality, often used for longer welding seems in thicker materials. During submerged arc welding one or more sequentially arranged welding electrodes melt in arcs.

[0003] The weld, particularly the melted material and the arc, are protected beneath a layer of pulverised flux. The flux melts in part during the process, thus creating a protecting layer of slag on the weld pool. The electrical current used in the process is relatively high, usually within 300-1500 Ampere per electrode. The electrodes used in submerged arc welding are usually 2,5 - 6 mm in diameter.

[0004] Fluxes used in submerged arc welding are granular fusible minerals typically containing oxides of manganese, silicon, titanium, aluminium, calcium, zirconium, magnesium and other compounds such as calcium fluoride. The flux is specially formulated to be compatible with a given electrode wire type so that the combination of flux and wire yields desired mechanical properties. All fluxes react with the weld pool to produce the weld metal chemical composition and mechanical properties. It is common practice to refer to fluxes as 'active' if they add manganese and silicon to the weld, the amount of manganese and silicon added is influenced by the arc voltage and the welding current level.

[0005] To find the highest productivity possible with submerged arc welding, with increased competitiveness as one result, one strives for increased weld speed and the highest possible deposition rate, i.e. melted welding consumables, or really created joint material, per hour and electrode.

[0006] When welding with a single electrode, as opposed to multiple sequential electrodes, the upper limit is often reached, making further improvements in the welding productivity impossible by only changing the weld data. For instance, when increasing the weld current the arc finally becomes strong enough to push the weld pool resulting in unacceptable welds.

[0007] One solution to this known in the art is to use multiple electrodes, positioned sequentially in the direction of the weld seem. Usually 2-3 electrodes are used, however, usage of up to 6 electrodes is known.

[0008] Unfortunately a multiple electrode set-up is not problem-free as the individual arcs affect each other through so called "magnetic arc blow effect". This effect is caused by magnetic fields generated by the current flowing through adjacent electrodes. The "magnetic arc blow effect" affects an adjacent arc, making it deviate or deflect from the usual and wanted direction, which is in most cases perpendicular to the material and in line with the electrode. This deviation can cause the arc(s) to push the weld pool in an unfavourable way resulting in a waveform weld and unacceptable overall results.

[0009] Furthermore the molten material in the weld pool is influenced by forces from the arcs forming a sensitive system that affects the pattern of waves in the weld pool. Fluid material is squeezed between the arcs so that the whole weld pool can be seen as a connected system of n-1 weld pools, n being the number of arcs.

[0010] To inhibit this phenomenon one known solution is to power the primer electrode with DC current while powering the sequential ones with AC current. Using AC current in these situations has been proven useful for a number of reasons. For instance, a shifting magnetic field does not reach the arc to the same extent, especially for instance in a deep weld joint, as vortexes in the base material inhibit the magnetic field dispersion, also with a directionally fluctuating magnetic field the arc deviations are no longer mono-directional, resulting in less impact on the weld pool. A further benefit with AC current on the sequential electrodes is an increased deposition rate.

[0011] Even though the above mentioned solutions increase the weld speed and deposition rate there appears to be an upper limit hard to surpass without jeopardising the quality of the welding result.

[0012] Pushing beyond the limit can cause instability in the welding process at the latter electrodes. This is expected to depend on the relatively larger weld pool found at this position caused by the melted consumables from the leading electrodes in combination with the push effect on the weld pool from the arcs. To a small degree this effect can be lessened by sequentially lowered weld currents used to power the latter electrodes, although the problem can not be fully avoided through this measure.

[0013] A submerged arc welding method and a submerged arc welding machine are disclosed in JP 2005342723. A method and an apparatus of submerged arc welding with electrodes in tandem are disclosed in US 5140140. An automatic welding device of the MIG/MAG type is disclosed in WO2007066013.

SUMMARY OF THE INVENTION

[0014] It is an object of the invention to provide an apparatus comprising an electrode assembly for arc welding which allows for improved weld speed. Another object of the invention is to provide a method with an improved weld speed in conjunction with a satisfying weld quality.

[0015] The objects are achieved by the features of the independent claims 1 and 7. The other claims and the description disclose advantageous embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] The present invention together with the above-mentioned and other objects and advantages may best be understood from the following detailed description of the embodiments, but not restricted to the embodiments, wherein is shown schematically:

Fig. 1	an example embodiment of an apparatus for performing a method according to the invention;
Fig. 2	a flow chart illustrating a procedure according to the invention; and
Fig. 3a, 3b	an example embodiment of an electrode assembly comprising 5 electrodes (Fig. 3a) and the electrode assembly with electrodes separated in distance due to a stability criterion violation of one electrode (Fig. 3b).

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

[0017] In the drawings, equal or similar elements are referred to by equal reference numerals. The drawings are merely schematic representations, not intended to portray specific parameters of the invention. Moreover, the drawings are intended to depict only typical embodiments of the invention and therefore should not be considered as limiting the scope of the invention.

[0018] Fig. 1 depicts schematically a welding arrangement for submerged arc welding comprising an electrode assembly 100 for welding a workpiece 10. In this example embodiment, the electrode assembly 100 comprises three electrodes 110, 112, 114 each held in a weld head jaw 140, 142, 144. The electrodes 110, 112, 114 are aligned to a weld seam (not shown) in sequential order and spaced apart in an equidistant manner.

[0019] Similar to MIG welding, submerged arc welding (SAW) involves formation of an arc between the continuously-fed bare wire electrodes 110, 112, 114 and the workpiece 10 while the electrode assembly 100 moves in welding direction 30. The electrodes 110, 112, 114 may be fed from coils 120, 122, 124 and guided by wire guides 130, 132, 134. Each electrode 110, 112, 114 may be supplied by a separate power source 40, 42, 44.

[0020] The process uses a flux to generate protective gases and slag, and to add alloying elements to the weld pool 12. An additional shielding gas is not required. Prior to welding, a thin layer 20 of flux powder is placed on the workpiece surface 16. The arc moves along a joint line in welding direction 30 and as it does so, flux is fed to the welding area by a flux feed hopper 50. As the arc is completely covered by the flux layer 20, heat loss is extremely low. This produces a thermal efficiency as high as 60%, compared with 25% for manual metal arc. There is no visible arc light, welding is virtually spatter-free and there is no need for fume extraction.

[0021] Submerged arc welding can be operated as a fully-mechanised or automatic process, but optionally it can be semi-automatic. Typical welding parameters are current, arc voltage and travel speed which all can affect bead shape, depth of penetration and chemical composition of the deposited weld metal.

[0022] Each electrode 110, 112, 114 is supplied with one or more sensor units 60, 62, 64 which monitoring one or more welding parameters such as current and/or arc voltage. The monitored parameter may be used as stability parameter for determining if the welding process at each electrode 110, 112, 114 is stable or if an instability occurs at one or more of the electrodes 110, 112, 114.

[0023] The sensor units 60, 62, 64 are coupled to a monitoring device 70 which comprises a unit 72 for determining if a stability criterion is violated by one of the electrodes.

[0024] Fig. 2 depicts a flow chart of a procedure for monitoring the stability of n electrodes of an electrode assembly, for instance n=3 for three electrodes 110, 112, 114 in Fig. 1.

[0025] In step 200 one or more stability parameters Stab_par are monitored for each electrode. In step 202 it is checked if the one or more stability parameters Stab_par are less or equal a predetermined stability criterion Crit. For instance, violation of the stability criterion Crit is detected when the stability parameter Stab_par of one or more of the electrodes changes by more than 5%, preferably by more than 10% with respect to the stability parameters of one or more adjacent electrodes, particularly of a leading electrode relative to a trailing electrode.

[0026] If the one or more stability parameters Stab_par is within the allowed range ("yes" in the flow chart), the routine jumps back to the monitoring step 200. If a violation of the one or more stability parameters Stab_par is detected ("no" in the flow chart), separating at least temporarily the electrode where the instability first occurs from one or more adjacent electrodes, particularly the electrode violating the stability criterion is separated from its leading electrode.

[0027] Fig. 3a and 3b show an example of an electrode assembly 100 comprising five electrodes 110, 112, 114, 116, 118. The electrodes 110, 112, 114, 116, 118 are equidistantly spaced by a distance d0, and inclined towards each other by an angle α. the distance d0 is here shown as distance between the end of the weld head jaws 140, 142, 144, 146, 148. The wire electrodes 110, 112, 114, 116, 118 are collinear with a longitudinal extension of the weld head jaws 140, 142, 144, 146, 148. The weld head jaws 140, 142, 144, 146, 148 extend over a lateral distance 150 at their lower ends.

[0028] If a violation of the stability criterion Crit is detected at electrode 116, the equidistant sequential order of the electrodes 110, 112, 114, 116, 118 shown in Fig. 3a is changed and electrode 116 is separated from its leading electrode 114 according to a first embodiment by shifting the weld head jaw 146 laterally away from the weld head jaw 144 thus increasing the distance d0 to a larger distance d1.

[0029] According to another embodiment (not shown) the electrode 116 can be separated from its leading electrode 114 by tilting the weld head jaw 146 and subsequently the weld head jaw 148 of the other trailing electrode 118 thus increasing the distance d0 to a larger distance d1. The lateral distance 150 of the lower ends of the weld head jaws 140, 142, 144,146, 148 increases subsequently.

[0030] According to another embodiment (not shown) the electrode 116 may be separated from its leading electrode 114 by shifting the weld head jaw 146 in a transverse direction thereby creating an arrangement where not all electrodes are aligned along the weld seam anymore.

[0031] The distance d0 can be preferably increased by a factor of 1,5, more preferably by a factor between 2 and 10, particularly by a factor between 2,5 and 5.

[0032] For instance, the increase in distance has been from the starting distance d0 of 20 mm to a distance d1 between 50 and 100 mm.

[0033] The electrode assembly 100 shown in Fig. 3b can also be a fixed electrode arrangement wherein the electrode 116 violating the stability criterion Crit has been determined by modelling and/or testing before the welding process. This is advantageous if such an electrode assembly 100 is used for routine welding processes with virtually constant requirements, for instance for welding large numbers of identical pipes.

[0034] Through this alteration welding with results within the desired quality levels can be achieved with previously unattained weld speeds. In a specific case it was shown that an increased distance by 100 mm between electrodes 114 and 115 in a 5-electrode system offered the sought after results. Of course, the numbers depend on the actual system and geometry and are only given for illustrating the effect. The numbers may differ in other arrangements.

Claims

1. An apparatus comprising an electrode assembly (100) for electric arc welding, comprising
at least three fusible continuously-fed electrodes (110, 112, 114, 116, 118) for generating a weld pool (12) via electric arcs in a workpiece (10),
a weld head jaw (140, 142, 144, 146, 148) arranged for each of the at least three electrodes (110, 112, 114, 116, 118) and wherein the at least three electrodes (110, 112, 114, 116, 118) are arranged in sequential order with respect to a welding direction (30) when the electrode assembly (100) is in an operating mode, and
an actuator arranged to connect to and to move each of the weld head jaws (140, 142, 144, 146, 148),
wherein at least one of the trailing electrodes (116) is geometrically separated from its leading electrode (114) in the welding direction (30) and/or transversally to the welding direction (30) compared to one or more foregoing electrodes (110, 112) of the leading electrode (114),
characterized in that it further comprises a monitoring device (70) coupled to sensor units (60, 62, 64) of each electrode for monitoring at least one stability parameter (Stab_par) for each electrode, the stability parameter being at least one of electric current through each electrode and arc voltage related to each electrode and a unit (72) for determining if the stability parameter (Stab_par) of one electrode of the electrode assembly (100) violates a stability criterion (Crit), and **in that** the actuator is arranged to increase a distance (d0) between the at least one trailing electrode (116) from its leading electrode (114) during welding when a monitored stability parameter (Stab_par) of the at least one trailing electrode (116) is observed to change by more than 5% with respect to a monitored stability parameter (Stab_par) of its leading electrode (114).

2. The apparatus according to claim 1, **characterized in that** the trailing electrode (116) is separated from its leading electrode (114) by larger distance (d1) than the leading electrode (114) from its foregoing electrode (112).

3. The apparatus according to claim 2, **characterized in that** the distance (d0) between the trailing electrode (116) and its leading electrode (114) is increased by a factor of 1.5, preferably by a factor between 2 and 10, more preferably by a factor between 2.5 and 5.

4. The apparatus according to any preceding claim, **characterized by** increasing the distance (d0) between the trailing electrode (116) and its leading electrode (114) by adjusting a tilting angle (α) of weld head jaws (140, 142, 144, 146, 148) of the electrodes (110, 112, 114, 116, 118).

5. The apparatus according to any preceding claim, **characterized in that** the trailing electrode (116) is separated from its leading electrode (114) both in the welding direction and transversally to the welding direction.

6. The apparatus according to any preceding claim, **characterized by** that the at least three fusible continuously-fed electrodes include five electrodes (110, 112, 114, 116, 118), wherein the fourth electrode (116) is separated from the third electrode (114) by a larger distance (d1) than an equidistant spacing (d0) between the other subsequent electrodes (110, 112, 114, 118).

7. An electric arc welding method, wherein an electrode

assembly (100) comprises at least three fusible continuously-fed electrodes (110, 112, 114, 116, 118) acting on a workpiece (10) for generating a weld pool (12) via electric arcs, wherein the at least three electrodes (110, 112, 114, 116, 118) are arranged in sequential order relative to a welding direction (30) and laterally separated relative to each other, **characterized by**

- monitoring at least one stability parameter (Stab_par) for each electrode (110, 112, 114, 116, 118) of the electrode assembly (100), the stability parameter being at least one of electric current through each electrode and arc voltage related to each electrode;
- determining if the stability parameter (Stab_par) of one electrode (116) of the electrode assembly (100) violates a stability criterion (Crit), wherein the stability criterion (Crit) indicates that the stability parameter (Stab_par) of the electrode (116) is observed to change by more than 5% with respect to a stability parameter (Stab_par) of an electrode (114, 118) adjacent to the electrode (116);
- separating at least temporarily the electrode (116) violating the stability criterion (Crit) from one or more adjacent electrodes (110, 112, 114, 118) when a violation of the stability criterion (Crit) of the one electrode (116) is detected, by increasing a distance (d0) in the welding direction between the one electrode (116) violating the instability criterion (Crit) and its adjacent electrode (114).

8. The method according to claim 7, **characterized in that** the distance (d0) between the one electrode (116) and its one or more adjacent electrodes (110, 112, 114, 118) is increased by a factor of 1.5, preferably by a factor between 2 and 10, more preferably by a factor between 2.5 and 5.

9. The method according to anyone of the claims 7 or 8, **characterized in that** increasing the distance between the one electrode (116) and its one or more adjacent electrodes (110, 112, 114, 118) is performed by arranging one or more electrodes (110, 112, 114, 116, 118) in a transverse direction with relation to the welding direction (30).

10. The method according to anyone of the claims 7 to 9, **characterized by** increasing the distance between the one electrode (116) and its one or more adjacent electrodes (110, 112, 114, 118) by adjusting a tilting angle (α) of the electrodes (110, 112, 114, 116, 118).

11. The method according to anyone of the claims 7 to 10, **characterized by** increasing the distance between the one electrode (116) and its one or more adjacent electrodes (110, 112, 114, 118) by increasing a distance between weld head jaws (140, 142, 144, 146, 148) holding the electrodes (110, 112, 114, 116, 118).

12. The method according to anyone of the claims 7 to 11, **characterized in that** violation of the stability criterion is detected when the stability parameter (Stab_par) of one or more of the electrodes (110, 112, 114, 116, 118) changes by more than 10% with respect to the stability parameters (Stab_par) of one or more adjacent electrodes (110, 112, 114, 116, 118).

13. The method according to anyone of the claims 7 to 12, **characterized in that** violation of the stability criterion is detected when the stability parameter (Stab_par) of one or more of the electrodes (110, 112, 114, 116, 118) changes by more than 10% with respect to the stability parameters (Stab_par) of the trailing electrode (116, 118) compared to its foregoing electrode (110, 112, 114).

14. The method according to anyone of the claims 7 to 13, **characterized in that** the separation of the one electrode (116) is performed during ongoing current flow through the electrodes (110, 112, 114, 116, 118).

Patentansprüche

1. Vorrichtung umfassend eine Elektrodenanordnung (100) zum elektrischen Lichtbogenschweißen, umfassend
mindestens drei schmelzbare kontinuierlich zugeführte Elektroden (110, 112, 114, 116, 118) zur Erzeugung eines Schmelzbades (12) über elektrische Lichtbögen in einem Werkstück (10),
eine Schweißkopfbacke (140, 142, 144, 146, 148), die für jede der mindestens drei Elektroden (110, 112, 114, 116, 118) angeordnet ist, und wobei die mindestens drei Elektroden (110, 112, 114, 116, 118) in sequentieller Reihenfolge in Bezug auf eine Schweißrichtung (30) angeordnet sind, wenn sich die Elektrodenanordnung (100) in einem Betriebsmodus befindet, und
einen Aktuator, der angeordnet ist, um jede der Schweißkopfbacken (140, 142, 144, 146, 148) zu verbinden und zu bewegen,
wobei mindestens eine der nachfolgenden Elektroden (116) in Schweißrichtung (30) und/oder quer zur Schweißrichtung (30) geometrisch von ihrer führenden Elektrode (114) getrennt ist, verglichen mit einer oder mehreren vorangehenden Elektroden (110, 112) der führenden Elektrode (114),
dadurch gekennzeichnet, dass sie ferner eine

Überwachungsvorrichtung (70) umfasst, die mit Sensoreinheiten (60, 62, 64) jeder Elektrode zur Überwachung mindestens eines Stabilitätsparameters (Stab_par) für jede Elektrode verbunden ist, wobei der Stabilitätsparameter mindestens einer des elektrischen Stroms durch jede Elektrode und der Lichtbogenspannung bezogen auf jede Elektrode ist, und eine Einheit (72) zum Bestimmen, ob der Stabilitätsparameter (Stab_par) einer Elektrode der Elektrodenanordnung (100) ein Stabilitätskriterium (Crit) verletzt, und dadurch, dass der Aktuator so angeordnet ist, dass er während des Schweißens einen Abstand (d0) zwischen der mindestens einen nachfolgenden Elektrode (116) von ihrer führenden Elektrode (114) vergrößert, wenn bei einem überwachten Stabilitätsparameter (Stab_par) der mindestens einen nachfolgenden Elektrode (116) beobachtet wird, dass er sich gegenüber einem überwachten Stabilitätsparameter (Stab_par) seiner führenden Elektrode (114) um mehr als 5% ändert.

2. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** die nachfolgende Elektrode (116) durch einen größeren Abstand (d1) von ihrer führenden Elektrode (114) getrennt ist als die führende Elektrode (114) von ihrer vorangehenden Elektrode (112).

3. Vorrichtung nach Anspruch 2, **dadurch gekennzeichnet, dass** der Abstand (d0) zwischen der nachfolgenden Elektrode (116) und ihrer führenden Elektrode (114) um den Faktor 1,5 erhöht wird, vorzugsweise um einen Faktor zwischen 2 und 10, insbesondere um einen Faktor zwischen 2,5 und 5.

4. Vorrichtung nach einem der vorhergehenden Ansprüche **gekennzeichnet durch** Erhöhen des Abstands (d0) zwischen der nachfolgenden Elektrode (116) und ihrer führenden Elektrode (114) durch Einstellen eines Neigungswinkels (a) des Schweißkopfbackens (140, 142, 144, 146, 148) der Elektroden (110, 112, 114, 116, 118).

5. Vorrichtung nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die nachfolgende Elektrode (116) sowohl in der Schweißrichtung als auch quer zur Schweißrichtung von ihrer führenden Elektrode (114) getrennt ist.

6. Vorrichtung nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet, dass** die mindestens drei schmelzbaren kontinuierlich zugeführten Elektroden fünf Elektroden (110, 112, 114, 116, 118) aufweisen, wobei die vierte Elektrode (116) von der dritten Elektrode (114) durch einen größeren Abstand (d1) als einen äquidistanten Abstand (d0) zwischen den anderen nachfolgenden Elektroden (110, 112, 114, 118) getrennt ist.

7. Elektrisches Lichtbogenschweißverfahren, wobei eine Elektrodenanordnung (100) mindestens drei auf ein Werkstück (10) einwirkende schmelzbare kontinuierlich zugeführte Elektroden (110, 112, 114, 116, 118) zur Erzeugung eines Schmelzbades (12) über elektrische Lichtbögen umfasst, wobei die mindestens drei Elektroden (110, 112, 114, 116, 118) relativ zu einer Schweißrichtung (30) sequentiell angeordnet und relativ zueinander seitlich getrennt sind, **gekennzeichnet durch**

- Überwachung von mindestens einem Stabilitätsparameter (Stab_par) für jede Elektrode (110, 112, 114, 116, 118) der Elektrodenanordnung (100), wobei der Stabilitätsparameter mindestens einer des elektrischen Stroms durch jede Elektrode und der Lichtbogenspannung bezogen auf jede Elektrode ist;
- Bestimmen, ob der Stabilitätsparameter (Stab_par) einer Elektrode (116) der Elektrodenanordnung (100) ein Stabilitätskriterium (Crit) verletzt, wobei das Stabilitätskriterium (Crit) darauf hinweist, dass beim Stabilitätsparameter (Stab_par) der Elektrode (116) beobachtet wird, dass er sich bezüglich eines Stabilitätsparameters (Stab_par) einer Elektrode (114, 118) benachbart zur Elektrode (116) um mehr als 5% ändert;
- Trennen der Elektrode (116), die das Stabilitätskriterium (Crit) verletzt, zumindest vorübergehend von einer oder mehreren benachbarten Elektroden (110, 112, 114, 118), wenn eine Verletzung des Stabilitätskriteriums (Crit) der einen Elektrode (116) festgestellt wird, durch Erhöhen eines Abstands (d0) in der Schweißrichtung zwischen der einen Elektrode (116), die das Instabilitätskriterium (Crit) verletzt, und ihrer benachbarten Elektrode (114).

8. Verfahren nach Anspruch 7, **dadurch gekennzeichnet, dass** der Abstand (d0) zwischen der einen Elektrode (116) und ihrer einen oder mehreren benachbarten Elektroden (110, 112, 114, 114) um den Faktor 1,5 erhöht wird, vorzugsweise um einen Faktor zwischen 2 und 10, insbesondere um einen Faktor zwischen 2,5 und 5.

9. Verfahren nach einem der Ansprüche 7 oder 8, **dadurch gekennzeichnet, dass** Erhöhen des Abstands zwischen der einen Elektrode (116) und ihrer einen oder mehreren benachbarten Elektroden (110, 112, 114, 118) durch Anordnen einer oder mehrerer Elektroden (110, 112, 114, 116, 118) in Querrichtung in Bezug zur Schweißrichtung (30) durchgeführt wird.

10. Verfahren nach einem der Ansprüche 7 bis 9, **gekennzeichnet durch** Erhöhen des Abstands zwi-

schen der einen Elektrode (116) und ihrer einen oder mehreren benachbarten Elektroden (110, 112, 114, 118) durch Einstellen eines Neigungswinkels (a) der Elektroden (110, 112, 114, 116, 118).

11. Verfahren nach einem der Ansprüche 7 bis 10 **gekennzeichnet durch** Erhöhen des Abstands zwischen der einen Elektrode (116) und ihrer einen oder mehreren benachbarten Elektroden (110, 112, 114, 118) durch Erhöhen eines Abstands zwischen den Schweißkopfbacken (140, 142, 144, 146, 148), die die Elektroden (110, 112, 114, 116, 118) halten.

12. Verfahren nach einem der Ansprüche 7 bis 11, **dadurch gekennzeichnet, dass** eine Verletzung des Stabilitätskriteriums erkannt wird, wenn sich der Stabilitätsparameter (Stab_par) einer oder mehrerer der Elektroden (110, 112, 114, 116, 118) gegenüber den Stabilitätsparametern (Stab_par) einer oder mehrerer benachbarter Elektroden (110, 112, 114, 116, 118) um mehr als 10% ändert.

13. Verfahren nach einem der Ansprüche 7 bis 12, **dadurch gekennzeichnet, dass** eine Verletzung des Stabilitätskriteriums erkannt wird, wenn sich der Stabilitätsparameter (Stab_par) einer oder mehrerer der Elektroden (110, 112, 114, 116, 118) gegenüber den Stabilitätsparametern (Stab_par) der nachfolgenden Elektroden (116, 118) im Vergleich zu ihren vorangehenden Elektroden (110, 112, 114) um mehr als 10% ändert.

14. Verfahren nach einem der Ansprüche 7 bis 13, **dadurch gekennzeichnet, dass** die Trennung der einen Elektrode (116) während des laufenden Stromflusses durch die Elektroden (110, 112, 114, 116, 118) durchgeführt wird.

Revendications

1. Appareil comprenant un ensemble d'électrodes (100) pour le soudage à l'arc électrique, comprenant :

au moins trois électrodes fusibles alimentées en continu (110, 112, 114, 116, 118) pour générer un bain de fusion (12) via des arcs électriques dans une pièce à usiner (10),

une tête de soudage à mâchoires (140, 142, 144, 146, 148) étudiée pour chacune des au moins trois électrodes (110, 112, 114, 116, 118), et dans lequel les au moins trois électrodes (110, 112, 114, 116, 118) sont disposées dans un ordre séquentiel par rapport à une direction de soudage (30) lorsque l'ensemble d'électrodes (100) est dans un mode de fonctionnement, et

un actionneur étudié pour la connexion avec chacune des têtes de soudage à mâchoires (140, 142, 144, 146, 148) et pour déplacer celles-ci,

dans lequel au moins l'une des électrodes postérieures (116) est séparée géométriquement de son électrode antérieure(114) dans la direction de soudage (30) et/ou transversalement à la direction de soudage (30) en comparaison avec une ou plusieurs électrodes (110, 112) qui précèdent l'électrode antérieure (114),

caractérisé en ce qu'il comprend en outre un dispositif de surveillance (70) couplé avec des unités de détection (60, 62, 64) de chaque électrode pour surveiller au moins un paramètre de stabilité (Stab_par) pour chaque électrode, le paramètre de stabilité étant au moins l'un parmi un courant électrique à travers chaque électrode et une tension d'arc en lien avec chaque électrode et une unité (72) pour déterminer si le paramètre de stabilité (Stab_par) d'une électrode de l'ensemble d'électrodes (100) n'est pas conforme à un critère de stabilité (Crit), et **en ce que** l'actionneur est étudié pour augmenter une distance (d0) entre l'au moins une électrode postérieure (116) par rapport à son électrode antérieure (114) pendant le soudage lorsqu'un paramètre de stabilité (Stab_par) surveillé de l'au moins une électrode postérieure (116) est observé comme variant de plus de 5% par rapport à un paramètre de stabilité (Stab_par) surveillé de son électrode antérieure (114).

2. Appareil selon la revendication 1, **caractérisé en ce que** l'électrode postérieure (116) est séparée de son électrode antérieure (114) d'une distance plus grande (d1) que l'électrode antérieure (114) par rapport à son électrode qui précède (112).

3. Appareil selon la revendication 2, **caractérisé en ce que** la distance (d0) entre l'électrode postérieure (116) et son électrode antérieure (114) augmente d'un facteur de 1,5, de préférence d'un facteur compris entre 2 et 10, de manière davantage préférée, d'un facteur compris entre 2,5 et 5.

4. Appareil selon l'une quelconque des revendications précédentes, **caractérisé par** l'augmentation de la distance (d0) entre l'électrode postérieure (116) et son électrode antérieure (114) en réglant un angle d'inclinaison (a) de mâchoires de tête de soudage (140, 142, 144, 146, 148) des électrodes (110, 112, 114, 116, 118).

5. Appareil selon l'une quelconque des revendications précédentes, **caractérisé en ce que** l'électrode postérieure (116) est séparée de son électrode antérieure (114) à la fois dans la direction de soudage et transversalement à la direction de soudage.

6. Appareil selon l'une quelconque des revendications précédentes, **caractérisé en ce que** les au moins trois électrodes fusibles alimentées en continu comprennent cinq électrodes (110, 112, 114, 116, 118), dans lequel la quatrième électrode (116) est séparée de la troisième électrode (114) par une plus grande distance (d1) qu'un espacement équidistant (d0) entre les autres électrodes subséquentes (110, 112, 114, 118).

7. Procédé de soudage à l'arc électrique, dans lequel un ensemble d'électrodes (100) comprend au moins trois électrodes fusibles alimentées en continu (110, 112, 114, 116, 118) agissant sur une pièce à usiner (10) pour générer un bain de fusion (12) via des arcs électriques, dans lequel les au moins trois électrodes (110, 112, 114, 116, 118) sont disposées dans un ordre séquentiel par rapport à une direction de soudage (30) et sont séparées latéralement les unes des autres, **caractérisé par**

- la surveillance d'au moins un paramètre de stabilité (Stab_par) pour chaque électrode (110, 112, 114, 116, 118) de l'ensemble d'électrodes (100), le paramètre de stabilité étant au moins l'un parmi un courant électrique à travers chaque électrode et une tension d'arc en lien avec chaque électrode ;
- la détermination si le paramètre de stabilité (Stab_par) d'une électrode (116) de l'ensemble d'électrodes (100) n'est pas conforme à un critère de stabilité (Crit), dans lequel le critère de stabilité (Crit) indique que le paramètre de stabilité (Stab_par) de l'électrode (116) est observé comme variant de plus de 5% par rapport à un paramètre de stabilité (Stab_par) d'une électrode (114, 118) adjacente à l'électrode (116) ;
- la séparation au moins temporaire de l'électrode (116) non-conforme au critère de stabilité (Crit) d'une ou plusieurs électrodes adjacentes (110, 112, 114, 118) lorsqu'une non-conformité au critère de stabilité (Crit) de cette électrode (116) est détectée en augmentant une distance (d0) dans la direction de soudage entre cette électrode (116) non-conforme au critère d'instabilité (Crit) et son électrode adjacente (114).

8. Procédé selon la revendication 7, **caractérisé en ce que** la distance (d0) entre cette électrode (116) et sa ou ses électrodes adjacentes (110, 112, 114, 118) augmente d'un facteur de 1,5, de préférence d'un facteur compris entre 2 et 10, de manière davantage préférée, d'un facteur compris entre 2,5 et 5.

9. Procédé selon l'une quelconque des revendications 7 ou 8, **caractérisé en ce que** l'augmentation de la distance entre cette électrode (116) et sa ou ses électrodes adjacentes (110, 112, 114, 118) est réalisée en disposant une ou plusieurs électrodes (110, 112, 114, 116, 118) dans une direction transversale par rapport à la direction de soudage (30).

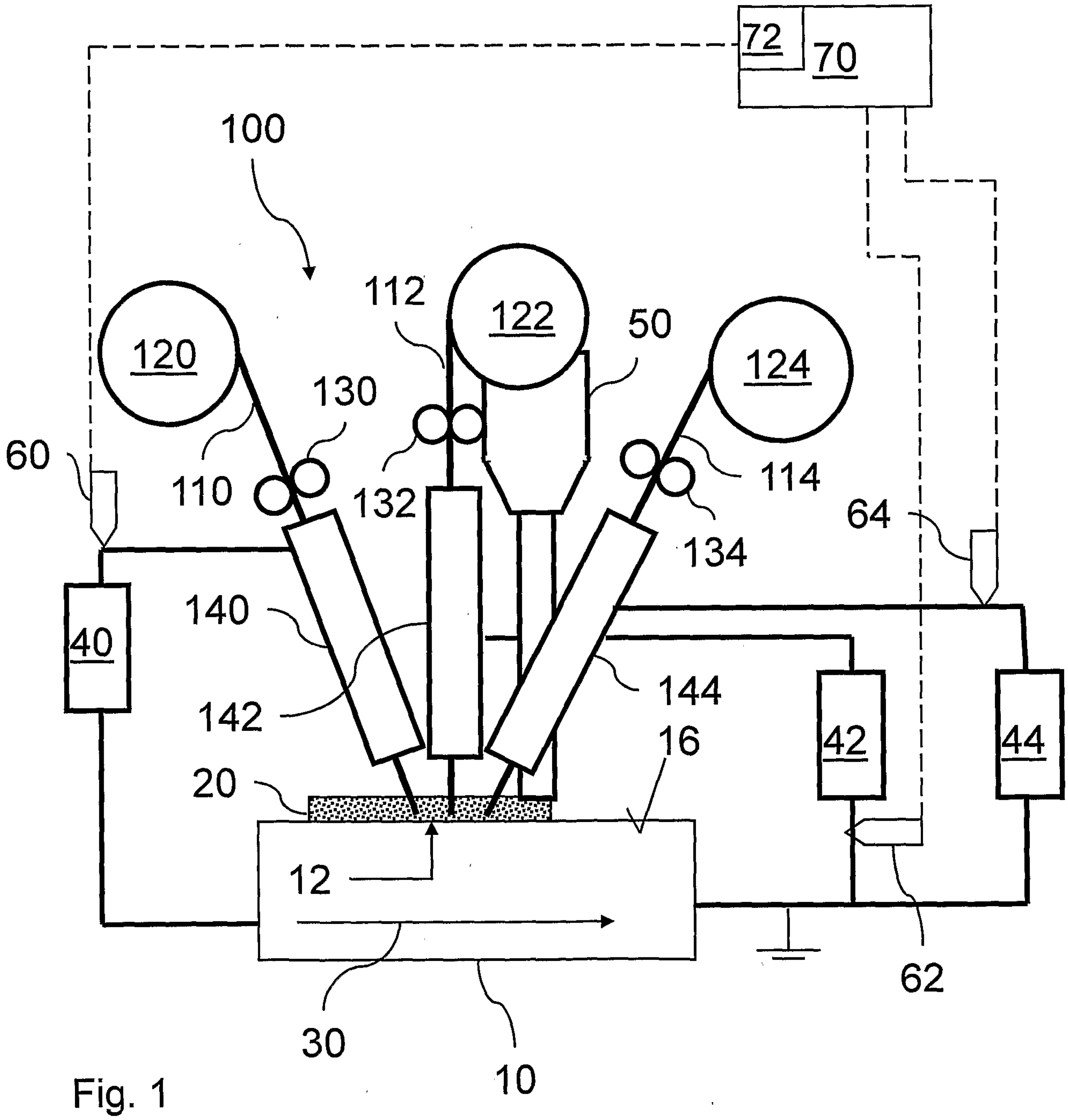
10. Procédé selon l'une quelconque des revendications 7 à 9, **caractérisé par** l'augmentation de la distance entre cette électrode (116) et sa ou ses électrodes adjacentes (110, 112, 114, 118) en réglant un angle d'inclinaison (a) des électrodes (110, 112, 114, 116, 118).

11. Procédé selon l'une quelconque des revendications 7 à 10, **caractérisé par** l'augmentation de la distance entre cette électrode (116) et sa ou ses électrodes adjacentes (110, 112, 114, 118) en augmentant une distance entre des mâchoires de tête de soudage (140, 142, 144, 146, 148) maintenant les électrodes (110, 112, 114, 116, 118).

12. Procédé selon l'une quelconque des revendications 7 à 11, **caractérisé en ce que** la non-conformité au critère de stabilité est détectée lorsque le paramètre de stabilité (Stab_par) d'une ou plusieurs électrodes (110, 112, 114, 116, 118) varie de plus de 10% par rapport aux paramètres de stabilité (Stab_par) d'une ou plusieurs électrodes adjacentes (110, 112, 114, 116, 118).

13. Procédé selon l'une quelconque des revendications 7 à 12, **caractérisé en ce que** la non-conformité au critère de stabilité est détectée lorsque le paramètre de stabilité (Stab_par) d'une ou plusieurs électrodes (110, 112, 114, 116, 118) varie de plus de 10% par rapport aux paramètres de stabilité (Stab_par) de l'électrode postérieure (116, 118) en comparaison avec son électrode qui précède (110, 112, 114).

14. Procédé selon l'une quelconque des revendications 7 à 13, **caractérisé en ce que** la séparation de cette électrode (116) est réalisée pendant une circulation de courant en cours à travers les électrodes (110, 112, 114, 116, 118).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112
122
50
120
124
130
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110
132
114
64
134
140
40
142
144
42
44
16
20
12
30
62
10

Fig. 1

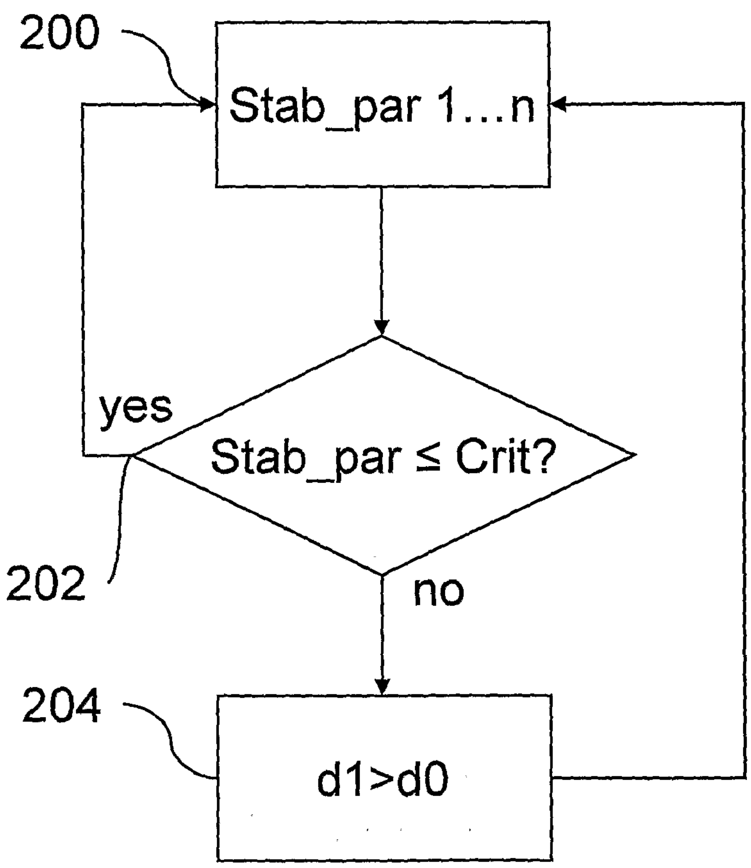

Fig. 2

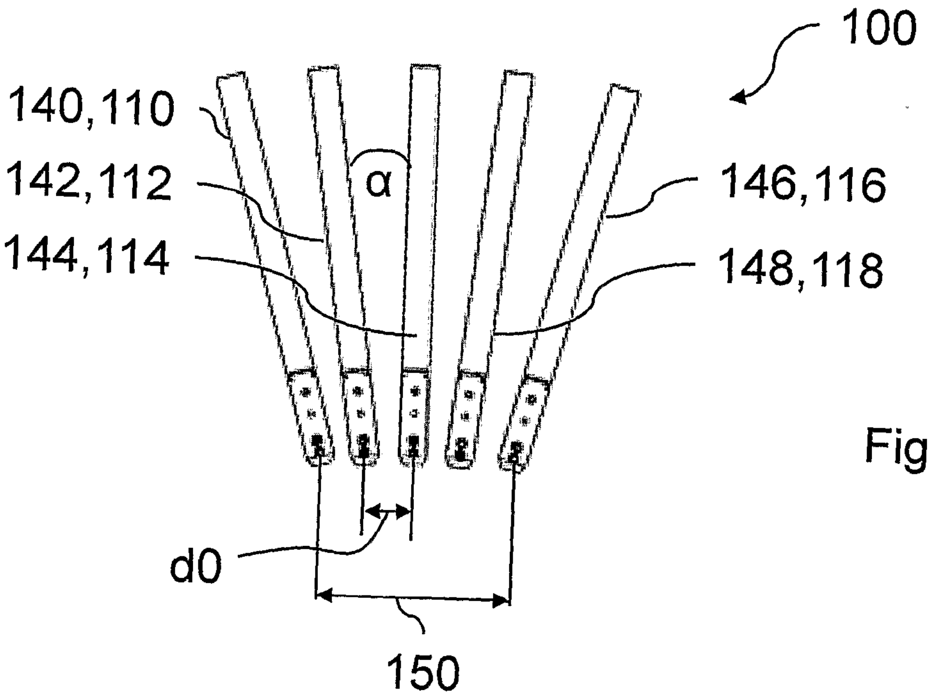
100
140,110
142,112
144,114
α
146,116
148,118
d0
150

Fig. 3a

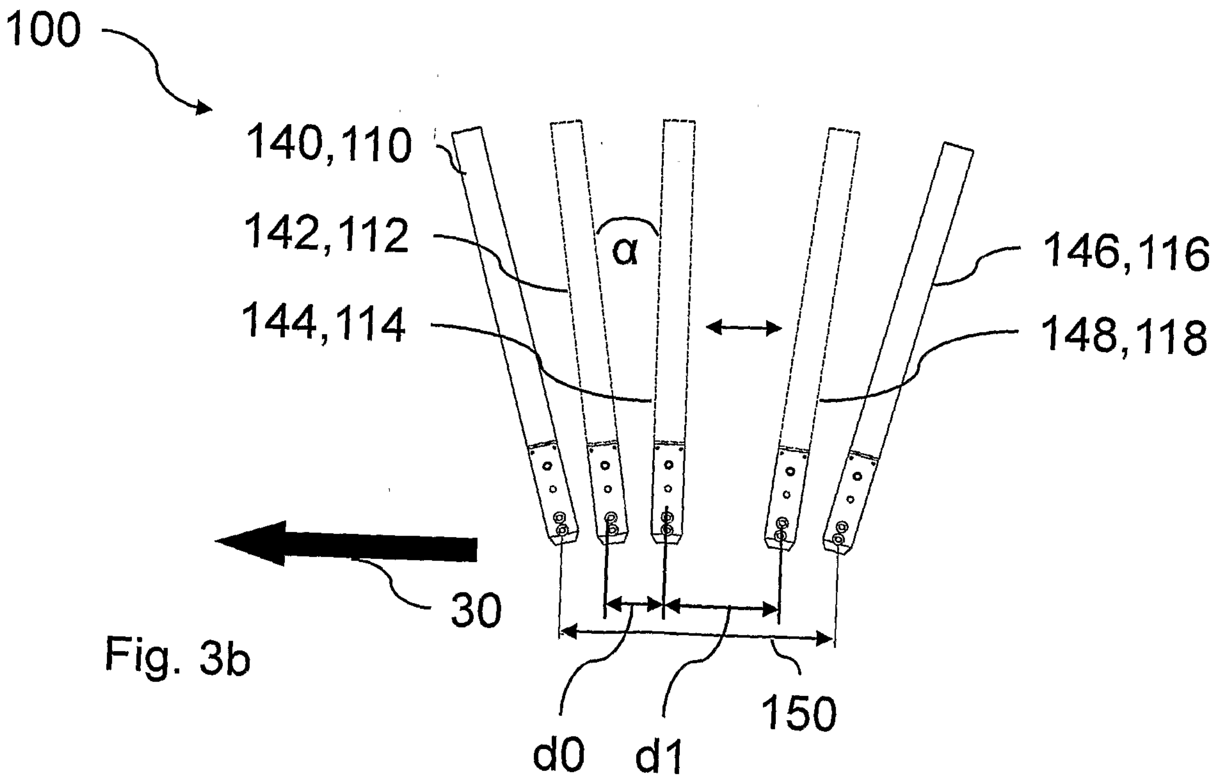
100
140,110
142,112
144,114
α
146,116
148,118
30
d0
d1
150

Fig. 3b

REFERENCES CITED IN THE DESCRIPTION

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